



ETM: Upper Class E Traffic Management

February 25, 2022

Recap

- Meeting October 5, 2021
 - Special Presentations
 - Recap of ETM Workshop
 - Presentation and discussion of AIA paper, “Cooperative operations in higher airspace- A Proposal”
 - Summary of publications:
 - Define Minimum Safe Operational Volume for Aerial Vehicles in Upper Class E Airspace
 - ETM Cooperative Operating Practices and Simulation Development for Use Case Demonstration

MERGED INFORMATION

- Information can be merged between two operators

COOPERATIVE RESOLUTION STAGES

- Two states exist in conflict resolution process:
 - Cooperative resolution
 - Failure
- Cooperative
 - Free
 - Stand

COOPERATIVE OPERATIONS IN HIGHER AIRSPACE

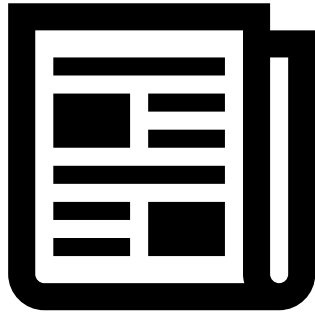
FAA/NASA/Industry Meeting
05 October 2021

Agenda

Pre-decisional

- News and Updates
 - HAPS Alliance
 - JARUS
 - Open forum
- Discussion of open items from previous AIA Presentation and next steps
- Briefing: Cooperative Separation in Upper Class E Airspace
Baseline Functional Requirements for Enabling Cooperative Separation Management
- Coming attractions
- Wrap up

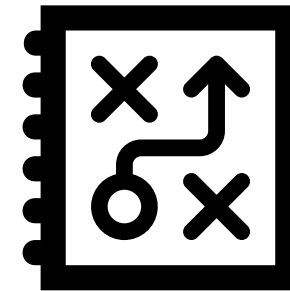
Industry Updates



News



Testing



Plans

AIA Presentation: Discussion

AIA Presentation: Discussion

Pre-decisional

- More clarity is desired on Industry's thoughts regarding what constitutes a conflict and your definition of a "rolling time horizon."
- Is there a plan from Industry with respect to defining "proximity thresholds," "confidence levels," "fallback rules," and "negotiation protocols"? Will AIA hold a series of dedicated working sessions to establish an Industry-informed position on these topics? There is also interest in understanding any current thoughts on the relevant parameters of each topic area.
- Would be good to hear thoughts on what "fairness" means from an Industry point of view in the context of resolutions/negotiations and to learn more about what a market-driven approach looks like.

AIA Presentation: Discussion

- More clarity is desired on Industry's thoughts regarding what constitutes a conflict and your definition of a "rolling time horizon."

AIA Response:

- We believe this should be further studied through operational analysis and simulation and then evaluating the results. Although this would be a much larger volume to consider, safety analysis and research has been done to define a detect and avoid (DAA) volume. That work is the basis for standards creation within RTCA.

AIA Presentation: Discussion

Pre-decisional

- Is there a plan from Industry with respect to defining “proximity thresholds,” “confidence levels,” “fallback rules,” and “negotiation protocols”? Will AIA hold a series of dedicated working sessions to establish an Industry-informed position on these topics? There is also interest in understanding any current thoughts on the relevant parameters of each topic area.

AIA Response:

- AIA is currently defining the 2022 work plan for Higher Airspace. Information and feedback from our Feb 25 meeting will help inform the work plan.

AIA Presentation: Discussion

- Would be good to hear thoughts on what “fairness” means from an Industry point of view in the context of resolutions/negotiations and to learn more about what a market-driven approach looks like.

AIA Response:

- An element for consideration in defining the concept of fairness for higher airspace operations should consider operations that have and don't have flexibility once airborne. Operation location/time, planned flight envelope, and aircraft operating characteristics are a few other elements that would need to be considered.

Upcoming Publications

Cooperative Separation in Upper Class E Airspace

Baseline Functional Requirements for Enabling Cooperative
Separation Management

Hyo-Sang Yoo, Jinhua Li, Ray Torres, Richard Jacoby,
Christopher O'hara, and Jeffrey Homola

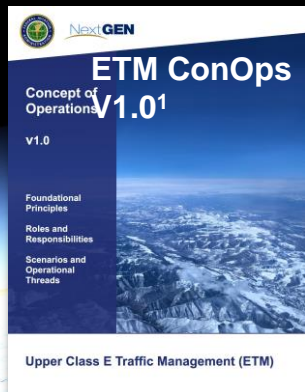
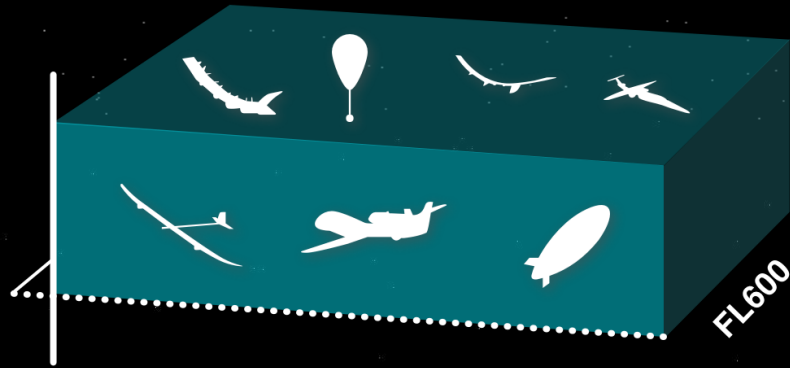
The need for Upper Class E Traffic Management (ETM) ?

New types of operations in upper Class E airspace

“in the United States, there are no airspace management provisions specific to civil aircraft operations above FL600¹”

Pre-decisional

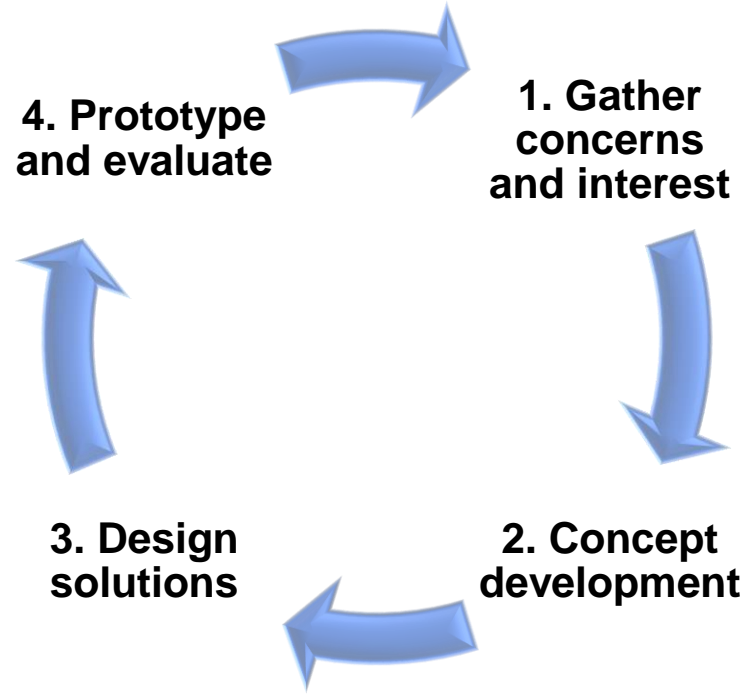
upper Class E airspace



The ConOps¹ states the opportunity of the alternative traffic management concept, which must:

- “Scale beyond the current NAS infrastructure and manpower resources to meet the needs of market forces”
- “Support the management of operations where no air navigation service provider (ANSP) separation services are desired, appropriate, and/or available”
- “Promote shared situation awareness among Operators”

Agile Development Approach

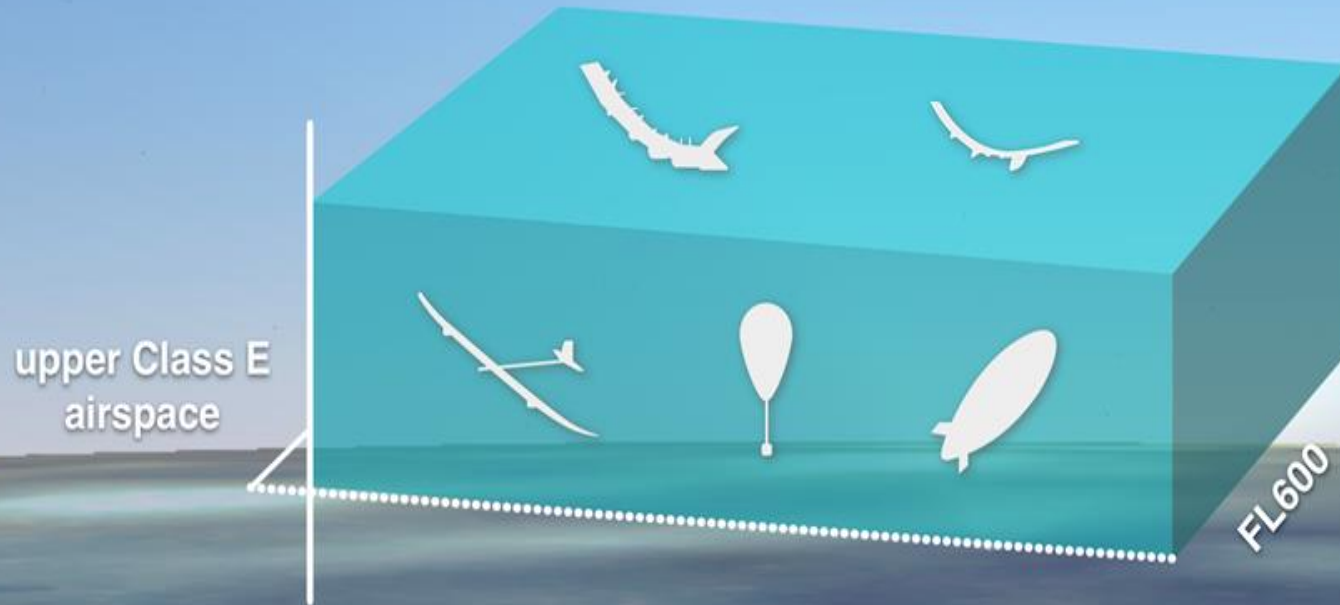


*The above process from 1 to 4 will be **iterative** to continuously refine the concept*

Goal : To improve current and new entrants vehicles to operate safely within the upper Class E airspace

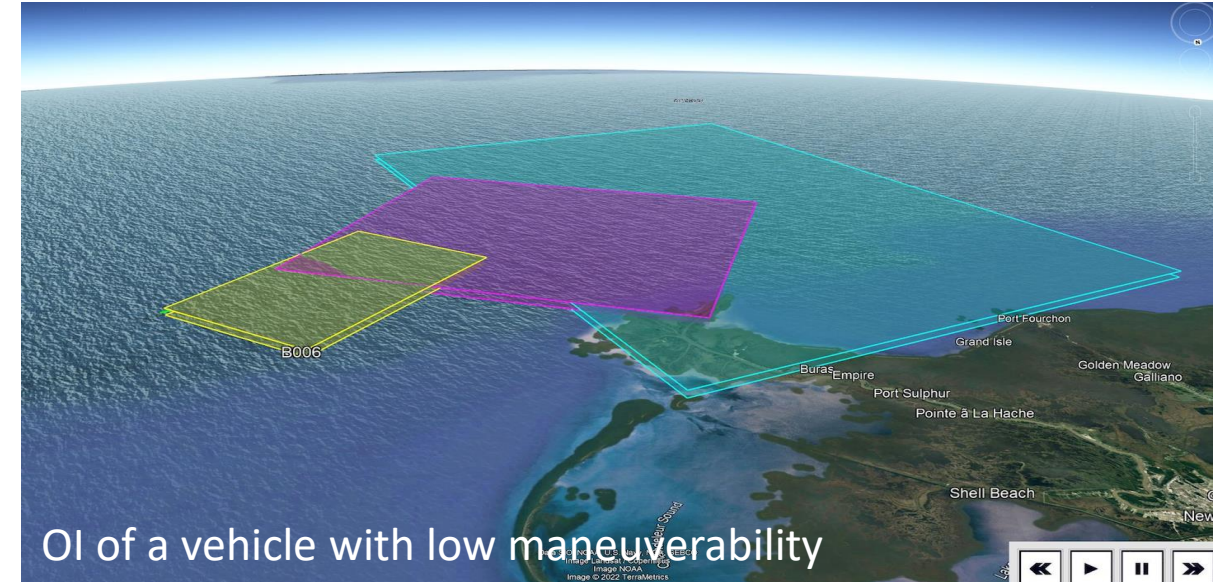
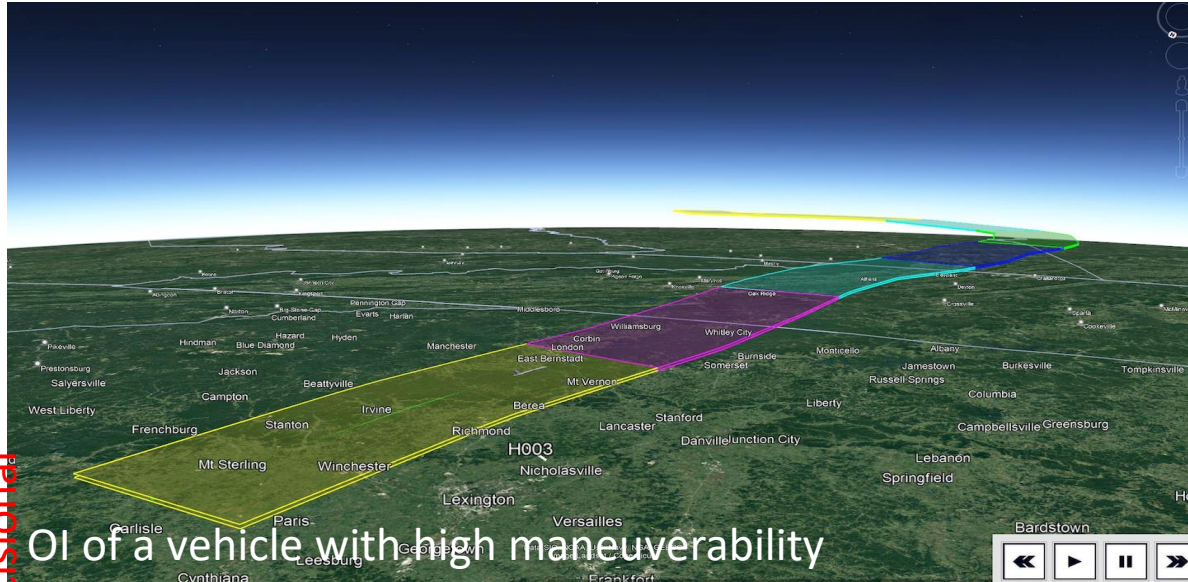
Scope

Pre-decisional



- The cruise phase (near and above FL600) of the HALE fixed-wing UAVs, balloons, and airship in the Upper Class E airspace.
- The climb and descent phases will be addressed as a separate research activity that will look at the Air Traffic Control (ATC) and ETM interactions.
 - The regulatory framework and requirements of ETM and ATC interactions are well described in the ETM ConOps v1.0¹ with various use case scenarios, including management of contingency events

Terms and Descriptions



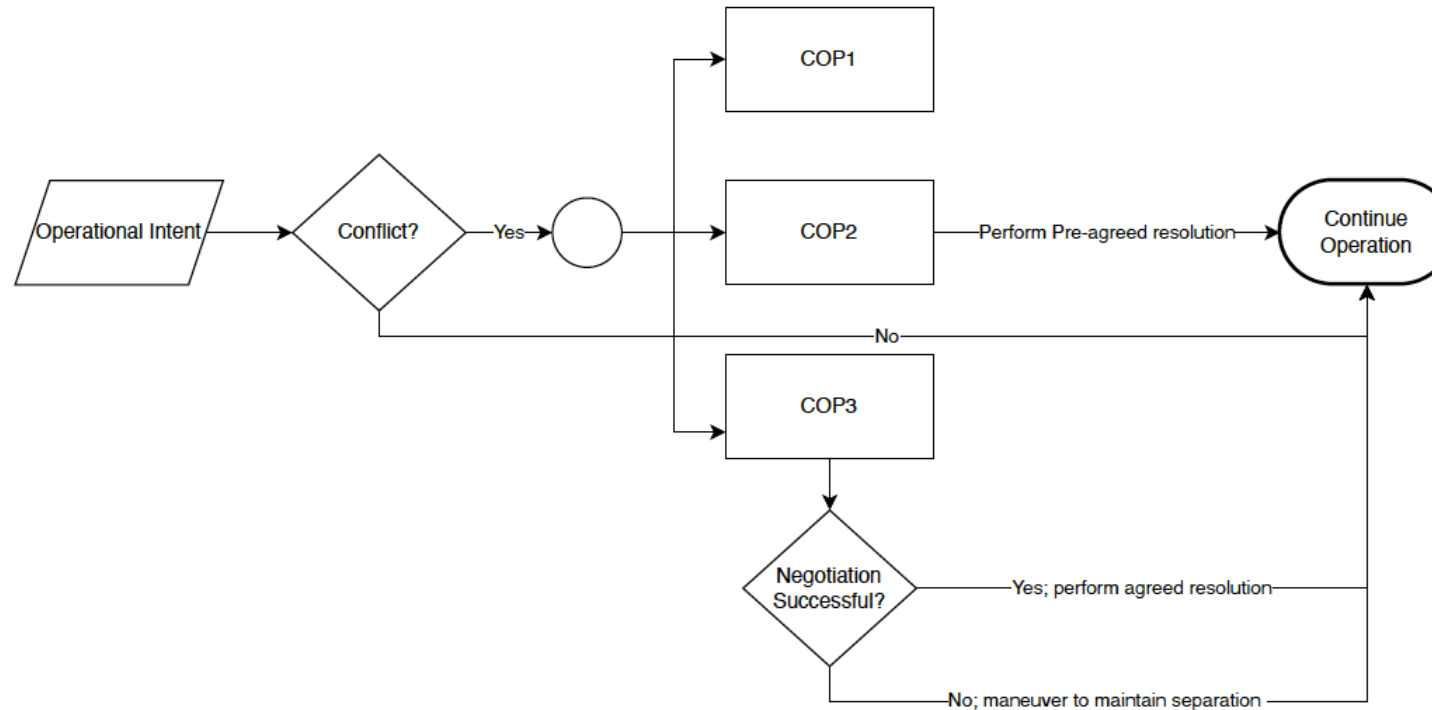
Operational Intent (OI): OI is “a type of information that is exchanged between operators that can be used to identify conflicts. It is four-dimensional (4D) (time and space) information that indicates, with a known level of confidence, where an aircraft will be at some given point in the future¹”

- OI bounds the intended flight operating volume. Operating volumes are 4D blocks of airspace with entry and exit times for the ETM vehicle.
- OI could be shared in a series of 4D volume segments, which represents full flight intent prediction over the next n -hour. The volume segments could overlay each other due to uncertainties.
- OI may be updated at a regular update rate using a “rolling-window” approach.”

- **Containment Confidence Level (CCL)** (= “the known level of confidence¹”): Indicates the level of confidence regarding adherence of the vehicle to stay safely within the 4D OI volume.
- **Conflict:** Situation where two or more OI volumes intersect in space and time .
- **Cooperative Operating Practices (COPs):** Set of pre-agreed operating rules and procedures to maintain separation while promoting safety cooperatively

Overview of Cooperative Separation Management (CSM)

“**Cooperative separation** is achieved via shared intent, shared awareness, de-confliction of operations, conformance monitoring, technologies supporting de-confliction, and the establishment of procedural rules of the road (e.g., right-of-way rules)¹”

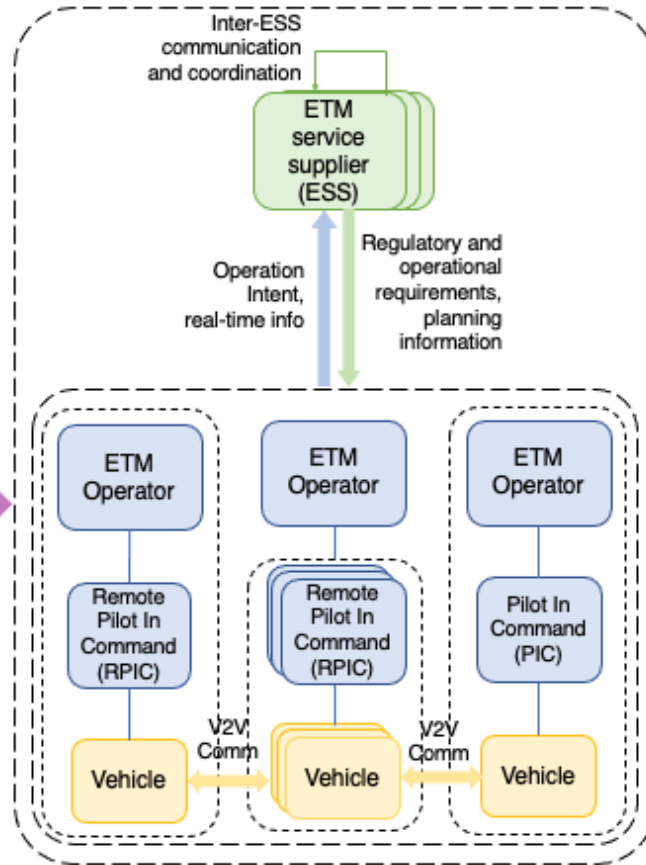


CSM will be organized, coordinated, and managed by a federated group of ETM operators through a set of agreed upon Cooperative Operating Practice (COP):

- COP1 serves as the baseline (default) de-confliction method based on a First-Reserved-First-Served (FRFS) principle
- COP2 indicates a pre-agreed method between ETM operators.
 - arrangements or negotiations are to be made in advance of operations
- COP3 allows the ETM operators to communicate directly and make real-time decisions in an *ad-hoc manner*
 - May be available in the absence of pre-established bilateral agreements between ETM operators
 - Must be available to address any unforeseen circumstances adaptively (e.g., a solar-powered HALE vehicle is not capable of moving due to low battery)
 - The “right-of-way rules” specified in 14 CFR § 91.113 could be used as the default initially, when the outcome is not reached within imparted time

The CSM operating environment

Pre-decisional

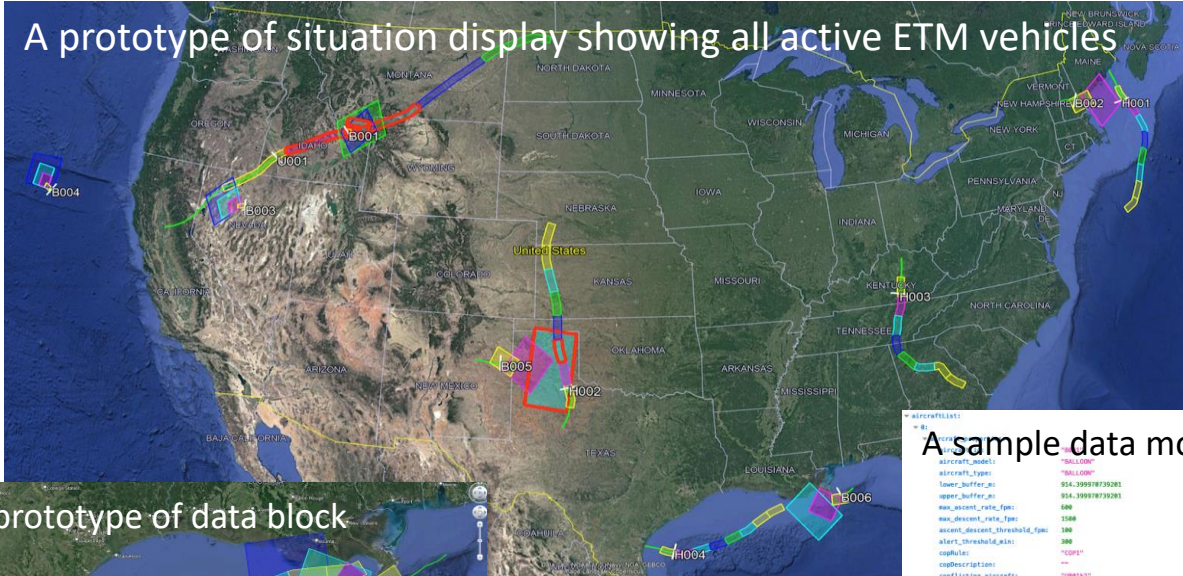


A key component of CSM operations in the ETM environment is the ESS (ETM Service Supplier). The roles of a ESS could be as follows:

- “Act as a communications bridge between ETM participants to support Operators’ abilities to meet the regulatory and operational requirements for Upper Class E operations¹”
- “Provide Operators with information about planned operations in and around a volume of airspace so that they can ascertain the ability to safely and efficiently conduct their mission¹”
- “Archive operations data in historical databases for analytics, regulatory, and Operator accountability purposes¹”

Operational Intent Sharing

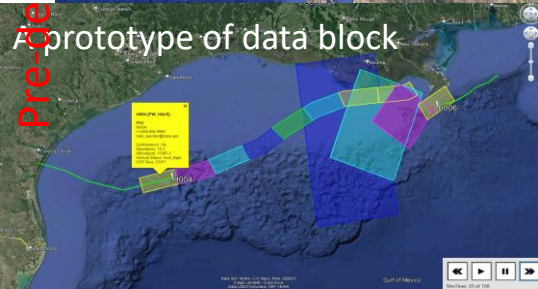
A prototype of situation display showing all active ETM vehicles



A sample data model of OI

[illegible]

A prototype of data block



A prototype of active aircraft table

A prototype of active aircraft table									
	Aircraft ID	Model	Type	Country	Altitude (m)	Ground Speed (ms)	Lat : Long	Wind (ms)	Vert Status
▶	B001	BALLOON	BALLOON	USA	18733.2	6.8	44.253 : -112.452	5.4	level_flight
	B002	BALLOON	BALLOON	USA	16688.4	34.7	43.636 : -72.527	18.3	level_flight
	B003	BALLOON	BALLOON	USA	17489	6.6	40.578 : -116.984	9.7	ascending
	B004	BALLOON	BALLOON	USA	19110.2	7.1	39.159 : -129.548	3.9	level_flight
	B005	BALLOON	BALLOON	USA	16343.2	31.8	35.272 : -104.569	17.4	level_flight
	B006	BALLOON	BALLOON	USA	17930.7	16.1	29.226 : -88.11	7.8	level_flight
	A001	BALLOON	BALLOON	USA	16623	14.8	15.994 : -119.731	7.8	level_flight
	H001	FW_HALE	FW_HALE	USA	18892.2	23.5	44.217 : -68.108	NA	level_flight
	H002	FW_HALE	FW_HALE	USA	19183.8	26.5	32.722 : -100.662	NA	level_flight
	H003	FW_HALE	FW_HALE	USA	18449.5	25.4	38.353 : -84.348	NA	level_flight
	H004	FW_HALE	FW_HALE	USA	17362.9	20.6	27.528 : -97.156	NA	level_flight

User story:

An ETM operator must share their vehicle's OI and can request nearby ETM vehicles' OIs through ESS data exchanges in order to support the planning and management of operations informed by accurate situation awareness of the operating environment.

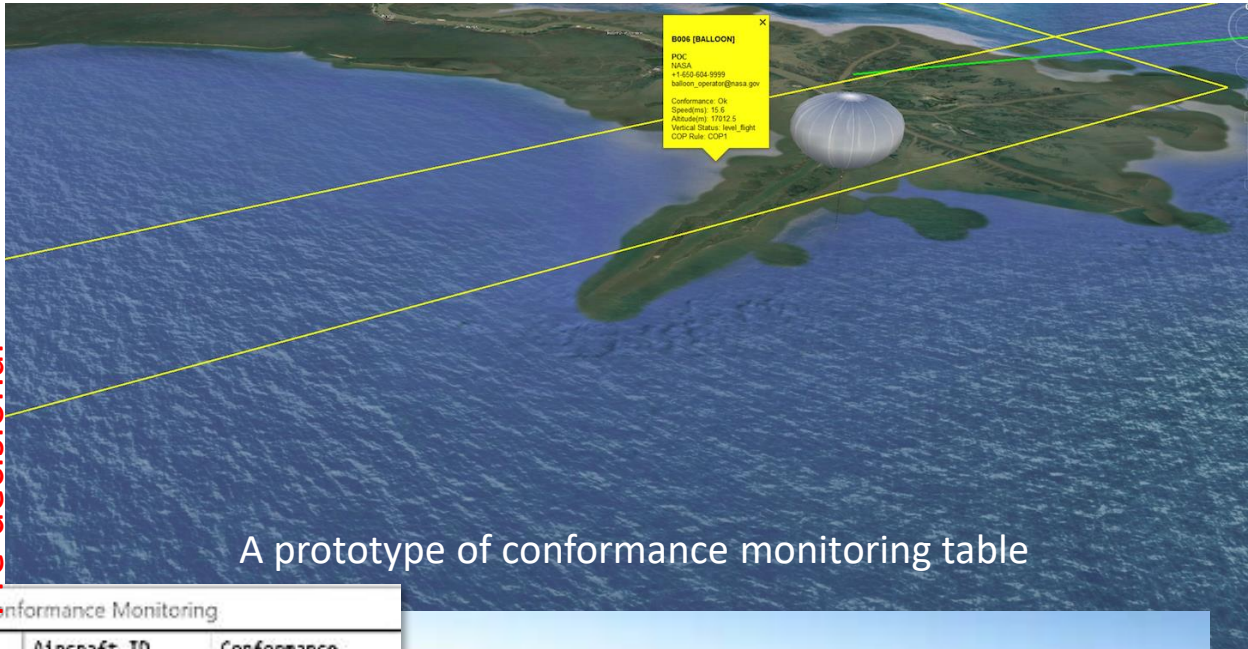
Acceptance Criteria:

- ETM operator(s) can submit an OI to the ESS and request all “accepted” and “activated” OI(s) in the ETM environment (above or near FL600)
 - The “accepted” state indicates that the OI meets all requirements to access and operate in the ETM environment but is not yet in use.
 - The “activated” state indicates that the operation is active and adhering to its requirements for operating in the prescribed airspace.
- ETM operator(s) can visualize and select all “accepted” and “activated” OI(s) to gather operational data in more detail for the airspace either planned for use or currently in use.

Functional Requirements (continued)

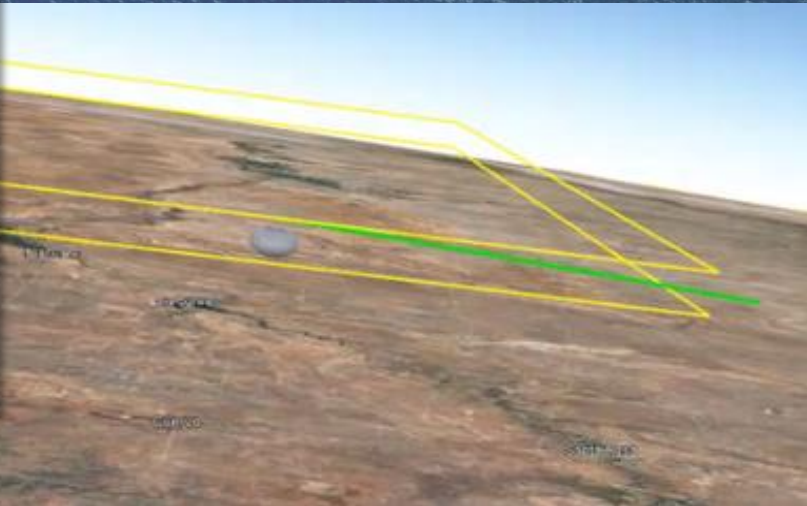
Conformance Monitoring

Pre-decisional



A prototype of conformance monitoring table

Conformance Monitoring	
Aircraft ID	Conformance
8001	Conforming
8002	Conforming
8003	Conforming
8004	Conforming
8005	Conforming
8006	Conforming
A001	Conforming
H001	Conforming
H002	Conforming
H003	Non-Conforming
H004	Conforming
U001	Conforming



User story:

An ETM operator can ensure that my vehicle stays safely within the published 4D OI volumes

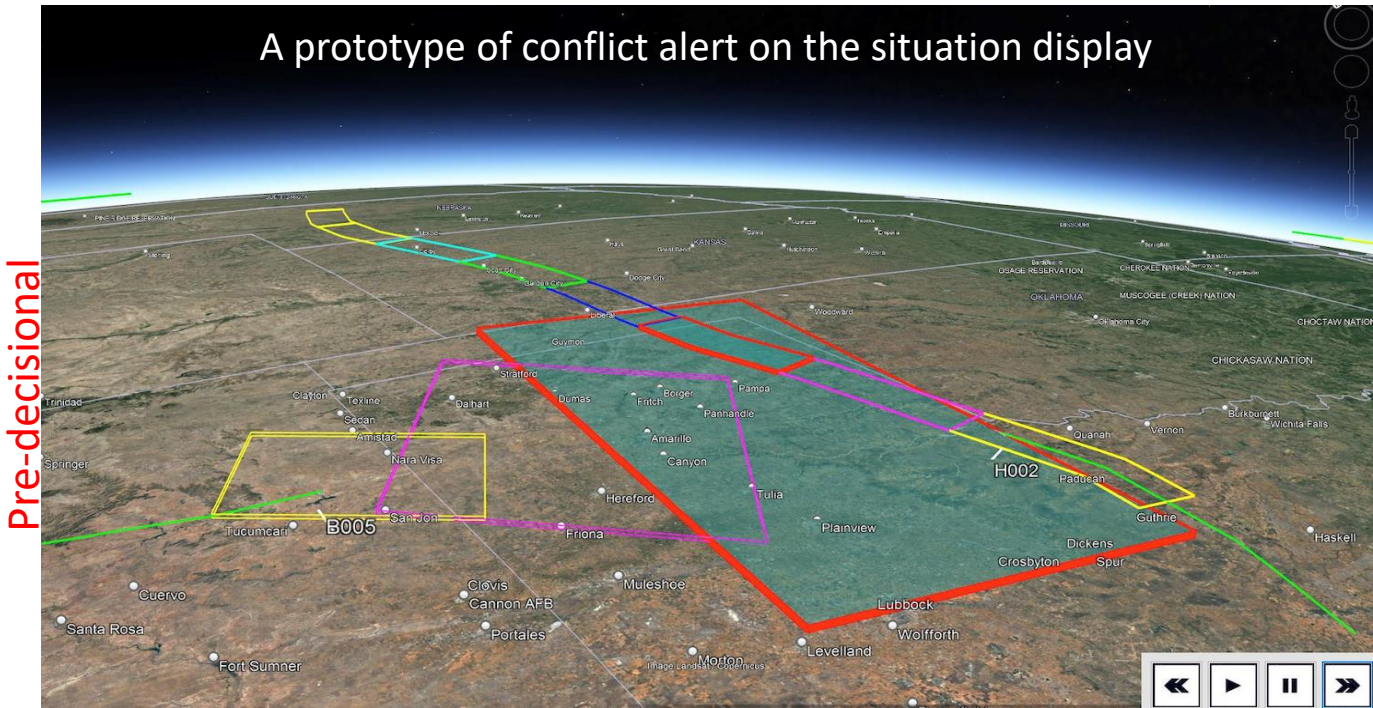
Acceptance Criteria:

- ETM operator(s) can view and track their operations in real-time
 - Flight operations data (i.e., telemetry information) and OI data must be available to support real-time vehicle conformance monitoring.
- ETM operator(s) will be notified by ESS when the trajectory is “nonconforming” or “contingent”
 - “Conforming” state is when the vehicle is flying within the OI.
 - “Nonconforming” state is when the vehicle is temporarily outside the spatial and/or temporal bounds of the OI but the situation is recoverable.
 - “Contingent” state is when that the operation is unable to return to conformance with the OI.

Functional Requirements (continued)

Conflict Detection

A prototype of conflict alert on the situation display



User story:

An ETM operator must submit OI to ESS and be notified if it intersects with another OI to enable deconfliction and promote safety.

Acceptance Criteria:

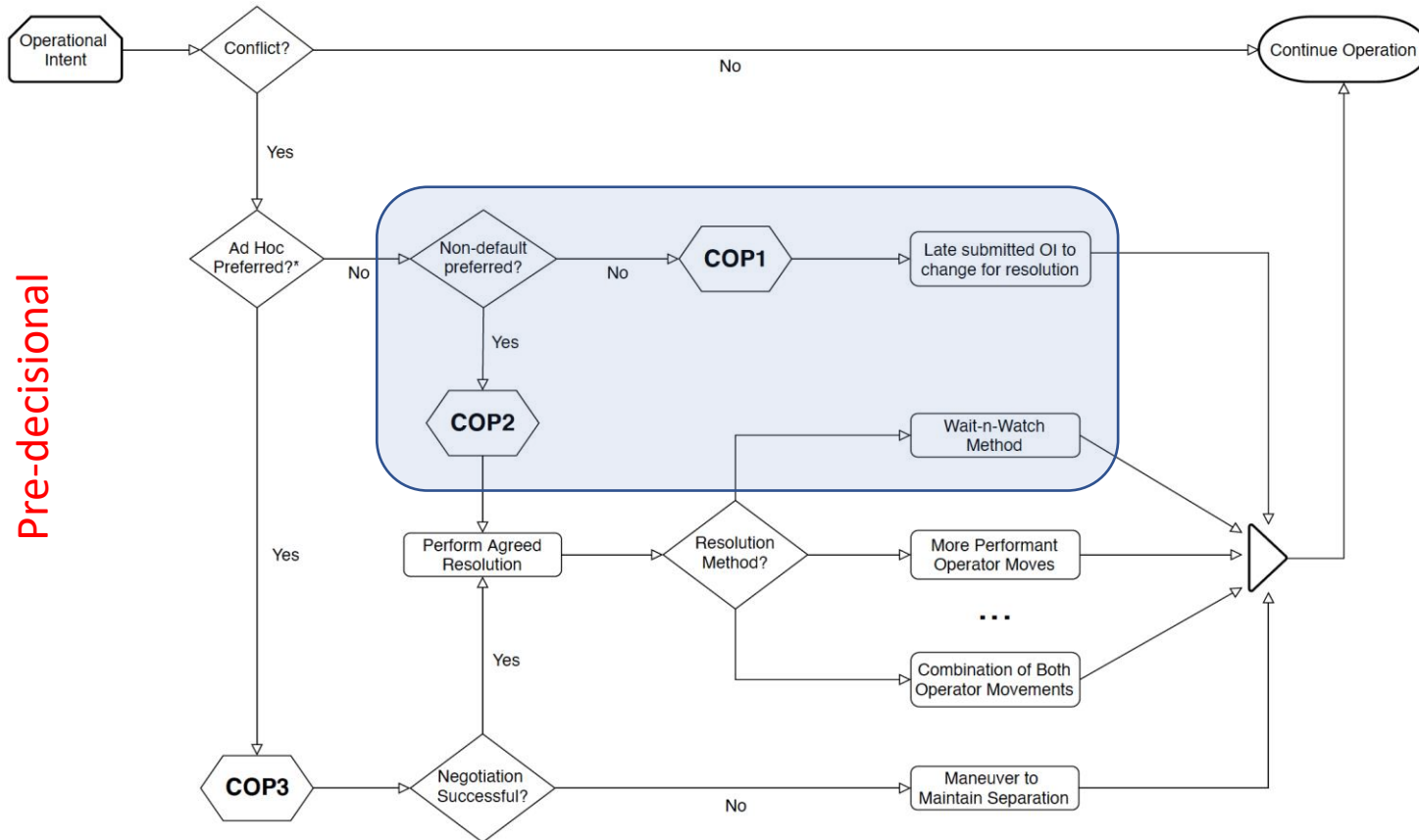
- ETM operator(s) (either or both) must be alerted in a timely manner (parameters TBD)
- ETM operator(s) must be notified with information to assess the criticality of the intersection

A prototype of conflict list table

	Aircraft ID 1	Flight Status 1	Flight Status 2	Aircraft ID 2	Time
▶	B001	-	^	H001	60
	B002	-	V	H003	120

Functional Requirements (continued)

Conflict Resolution



User story:

An ETM operator must be notified in a timely manner of which pre-agreed resolution method (COP1 and COP2) to be executed, if applicable, or to coordinate in ad-hoc negotiations (COP3) with the other ETM operator in order to maintain separation of OIs

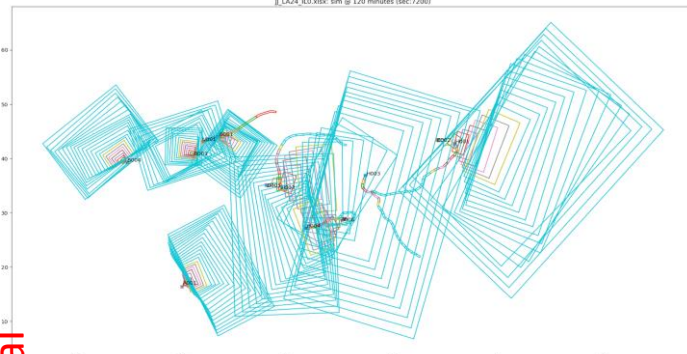
Acceptance Criteria:

- ETM operator(s), who pre-agreed on the standard rule-based approach (COP1 or COP2), must be notified on time regarding the type of resolution method to be executed
- ETM operator(s) can resolve the conflict through ad-hoc negotiation (COP3) if the method is coordinated with another conflicting ETM operator

Functional Requirements (continued)

Conflict Resolution (COP 2 – Use of Containment Confidence Level Information)

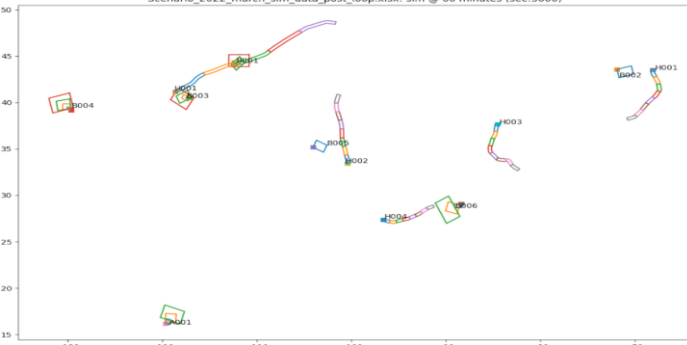
No OI size restriction, OI lookahead time horizon = 24 hours



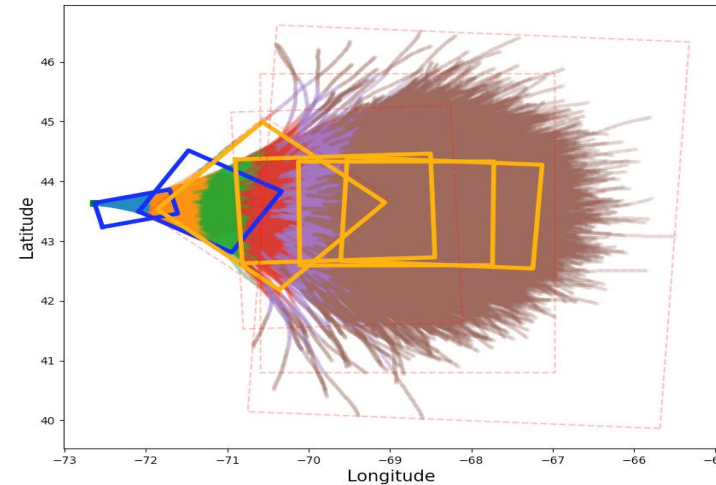
OI size restriction = 120, OI lookahead time horizon = 24 hours



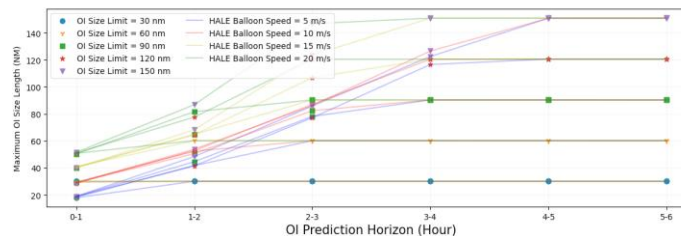
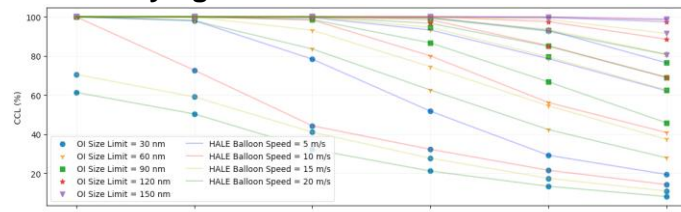
OI size restriction = 120, OI lookahead time horizon = 8 hours



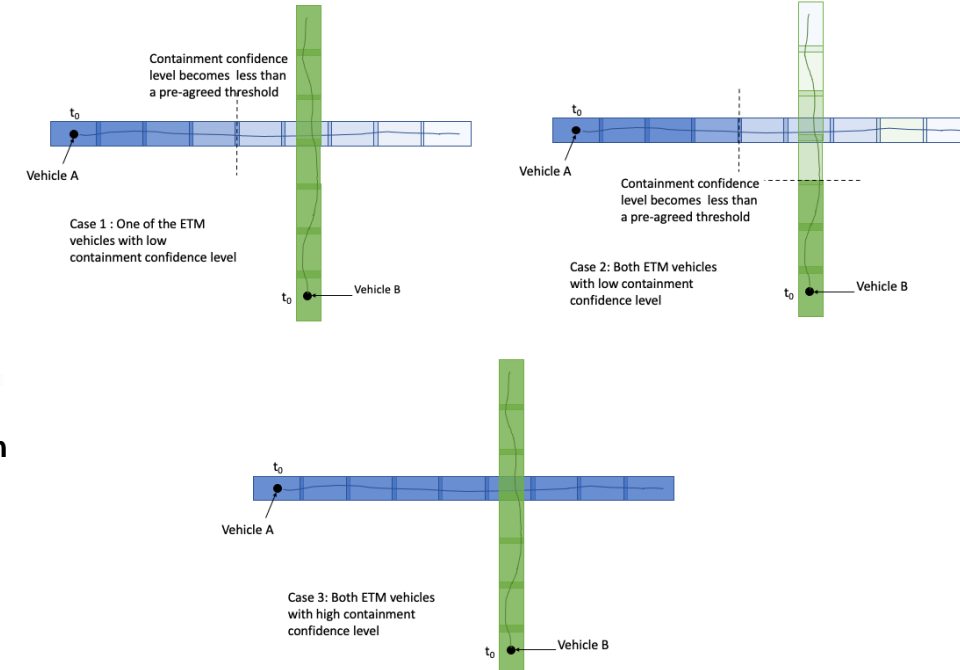
HALE balloon OI generation while meeting OI size restriction



Containment Confidence Level (CCL) computation under varying OI size restriction values

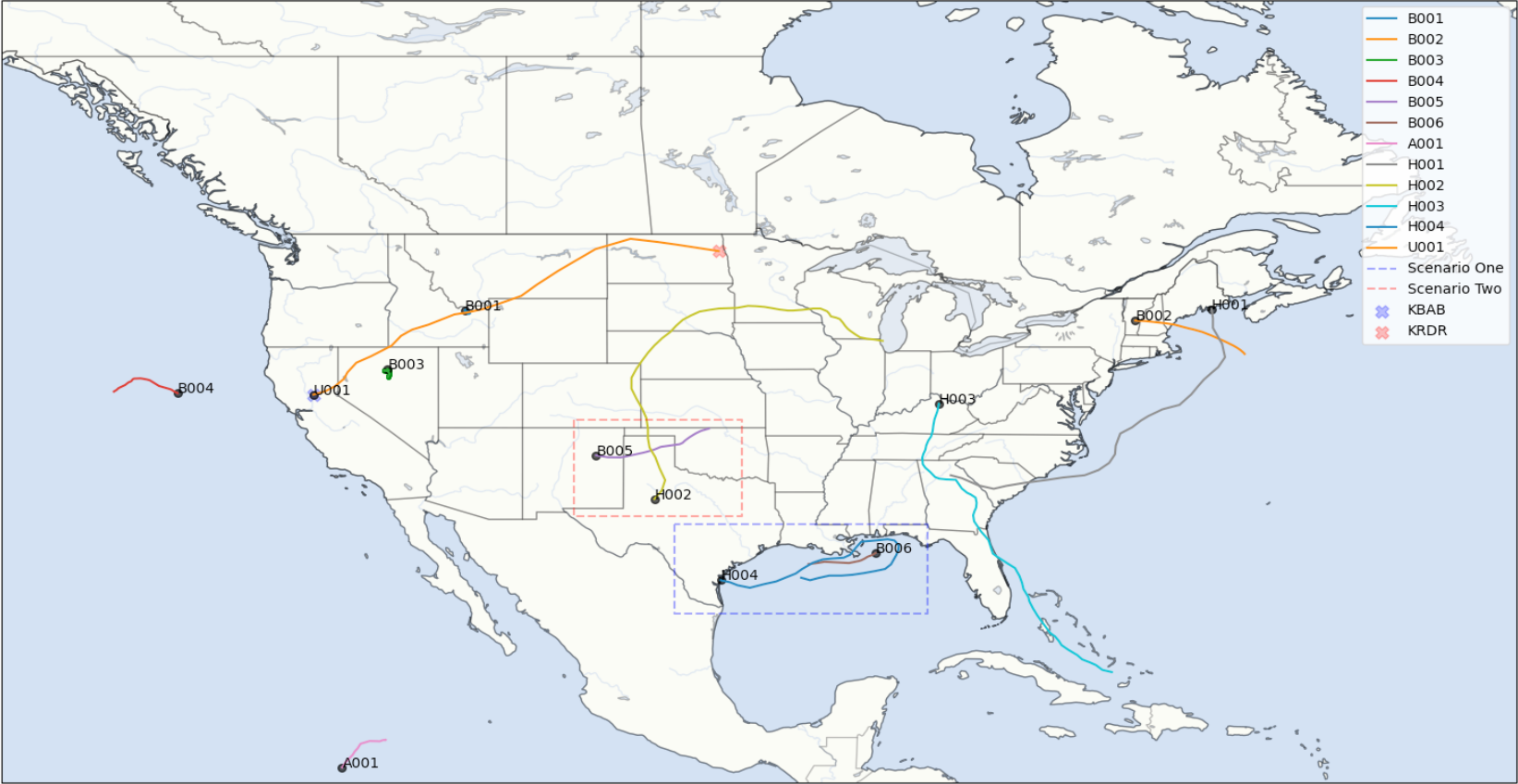


Containment Confidence Level
= $1 - (\text{likelihood that an ETM vehicle exits OI boundary})$



“Wait-n-watch” can be executed, if the intersecting OI segment’s CCL value is lower than the pre-agreed threshold value

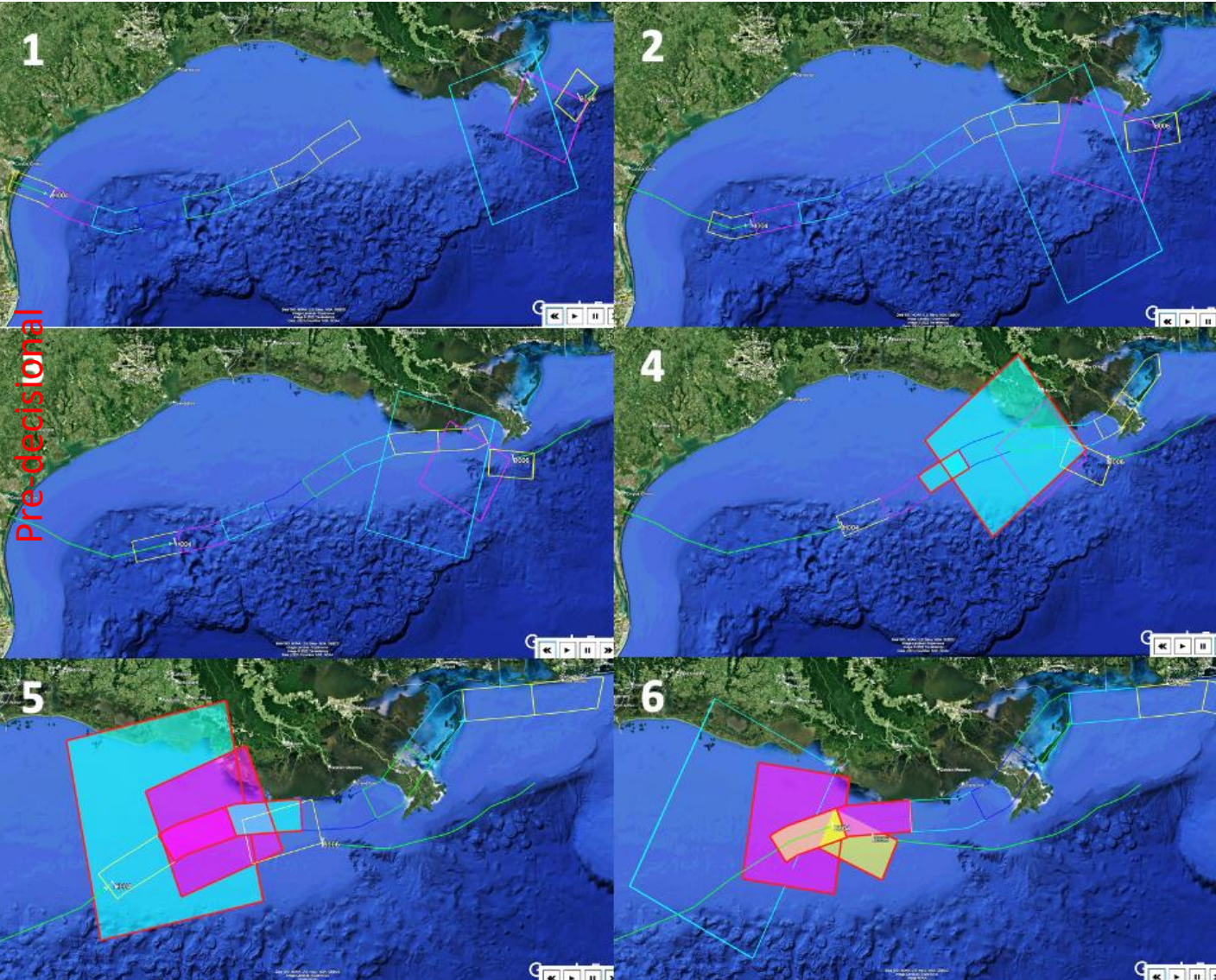
Overview of Scenario and Use cases



Element	Assumption
Airspace	<ul style="list-style-type: none">• Upper Class E airspace (near and above FL600)
Air Traffic Controller (ATC)	<ul style="list-style-type: none">• ATC is not providing separation services for ETM vehicles operating in Upper Class E airspace (near and above FL600)• (Verbal) communications between ATC and ETM operators, ESS are not required with the presumption that ATC has pre-authorized the ETM operators to have access to the ETM environment
Airspace Constraints	<ul style="list-style-type: none">• No airspace constraints currently present in the Upper Class E airspace with mild weather conditions
Operational Intent (OI)	<ul style="list-style-type: none">• OIs of the ETM vehicles are updated via the rolling-window approach
Cooperative Operating Practices (COPs)	<ul style="list-style-type: none">• Pre-agreed resolution methods (COP1 and COP2) exist between ETM vehicles• A primitive ad-hoc negotiation method (COP3) is available via phone call/email

Overview of Scenario and Use cases

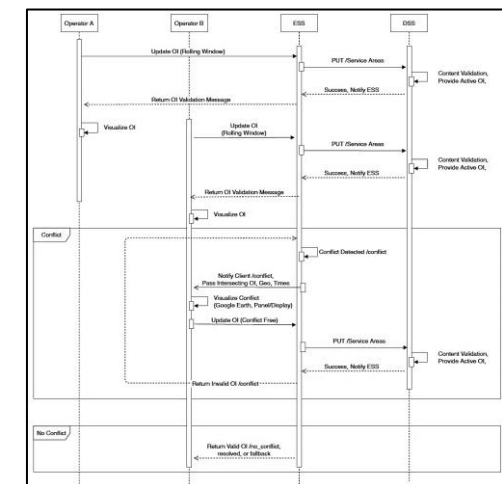
B006 – H004 interaction



Scenario Overview:

- A HALE balloon (B006) is flying over the Gulf of Mexico to monitor oil spills at 18.3 knots in average
 - Due to limited predictability, the HALE balloon (B006) operator shares its OI only up to next three hours
 - The OI is updated regularly at every 60-minute interval.
- A solar-powered HALE fixed-wing UAV (H004) is flying from Corpus Christi to the Gulf of Mexico to provide communication service over the Gulf of Mexico after the hurricane. Its intended flying speed is 20 knots
 - The HALE fixed-wing UAV (H004) operator shares its OI with 8-hour lookahead time and regularly updates OI at every 60-minutes interval.
 - Each polygon-shaped 4D volume OI represents every one-hour period of operations

➔ Three Use Cases (COP1, COP2 and COP3) can be tested using the same scenario

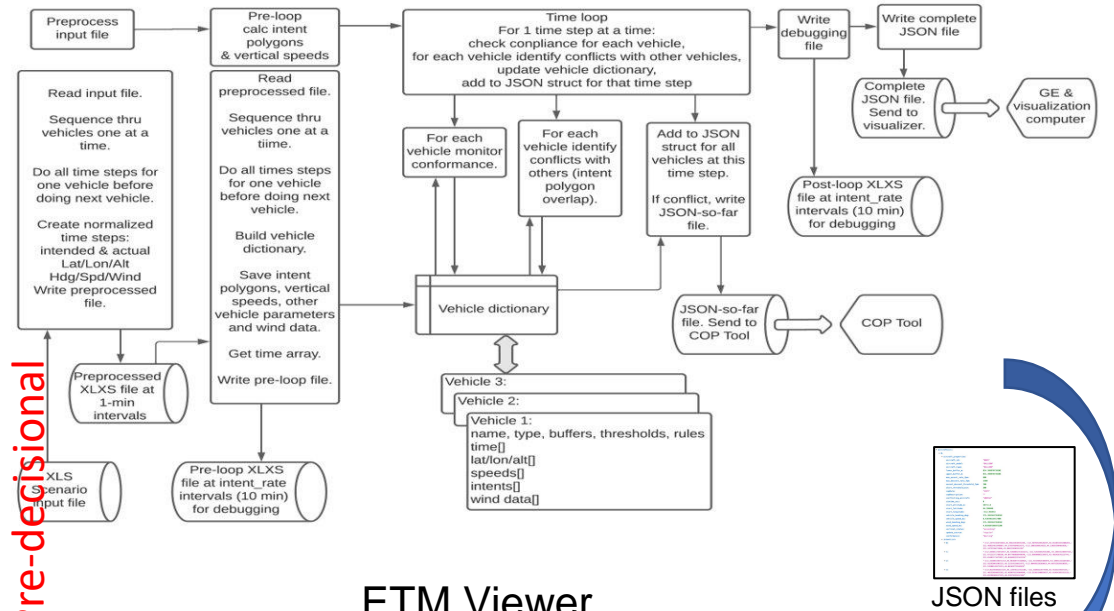


Potential communication between operators

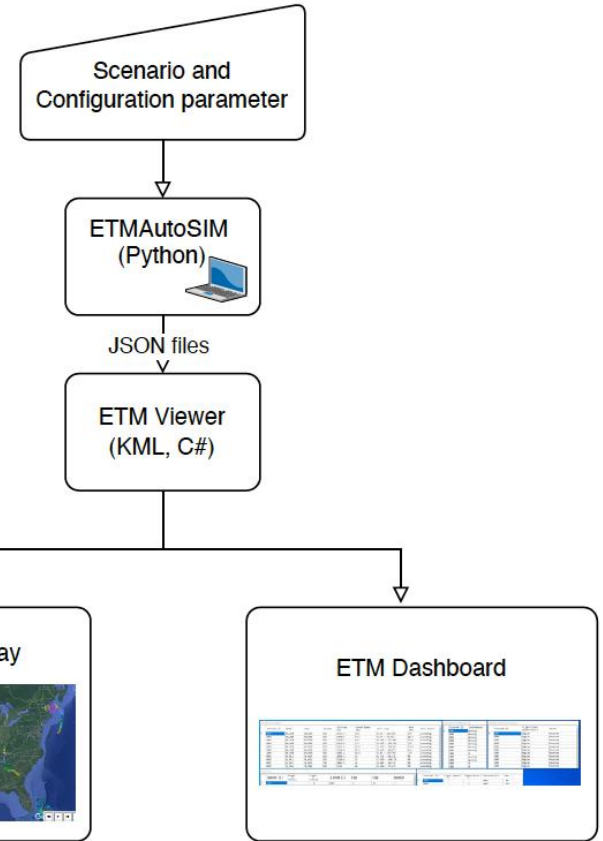
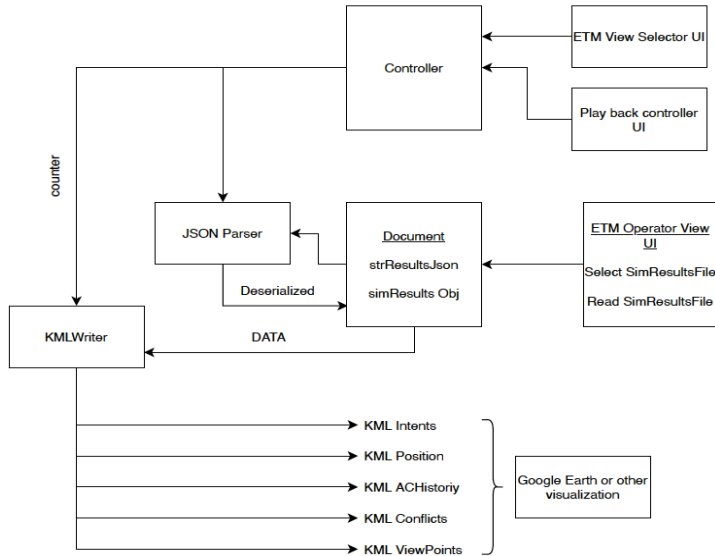
Simulation Environment (ETMAutoSIM and ETM Viewer)

ETMAutoSIM

ETMAutoSim Architecture-V2 (Time-first)



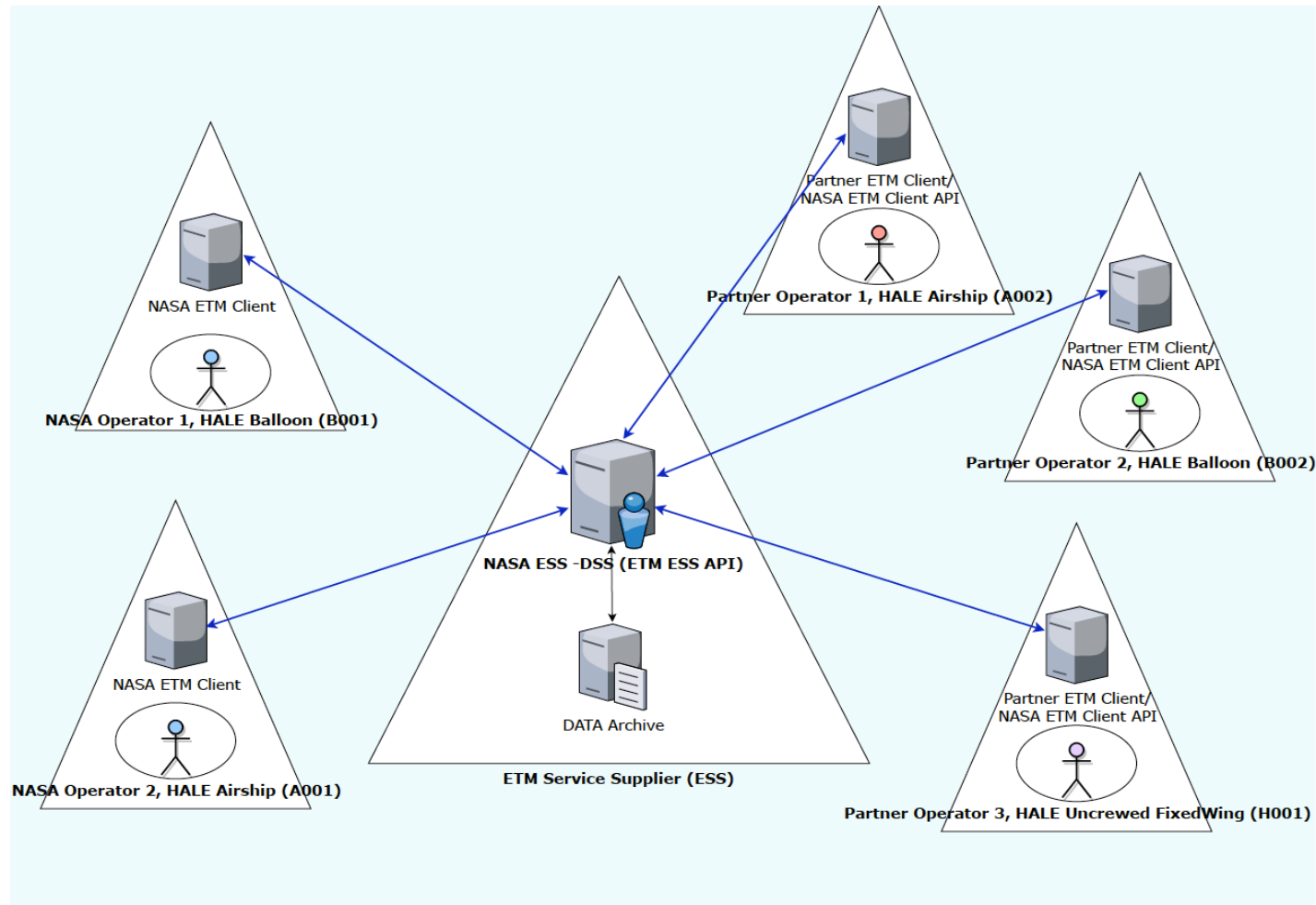
ETM Viewer



A block diagram of ETMAutoSIM + ETM Viewer

External Interfaces

Pre-decisional



[ETM-ETM Operator-API]: <https://github.com/nasa/utm-docs/tree/master/etm/operator-interface-spec>

[ETM-ESS-API]: <https://github.com/nasa/utm-docs/tree/master/etm>

Demonstration

A placeholder for video

Coming Attractions

Coming Attractions

- Announcement of Collaborative Opportunity (ACO) in the works and to be released when complete (date TBD)
- Working toward an ETM connectivity evaluation in Spring 2023
 - Stay tuned for details
- Additional publications in the works and to be formally released after final reviews and release authorization
- Upcoming session at AUVSI XPONENTIAL April 25-28 in Orlando, FL: NASA IS DEFINING THE FUTURE OF AIR TRAFFIC MANAGEMENT
- Proposal for next ETM meeting on the topic of communications considerations for ETM operators

Wrap up

Questions?

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